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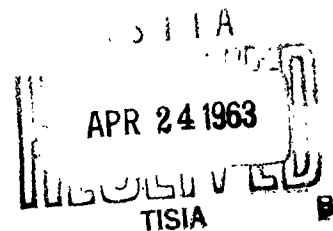
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MEMORANDUM REPORT NO. 1448
JANUARY 1963

TWO WAVELENGTH, STREAK INTERFEROMETRY
OF AN IONIZED, HEAVY GAS

F. D. Bennett
H. S. Burden
D. D. Shear



RDT & E Project No. 1A222901A201
BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

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B A L L I S T I C R E S E A R C H L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1448

FDBennett/HSBurden/DDShear/mec
Aberdeen Proving Ground, Md.
January 1963

TWO WAVELENGTH, STREAK INTERFEROMETRY OF AN IONIZED, HEAVY GAS

ABSTRACT

The problem of measuring interferometrically both the mass density and the electron concentration in an ionized gas requires interferograms at 2 different wavelengths. Transient ionized gases can be examined by the method of streak interferometry. By inserting a dichroic mirror-divider and duplicate optical trains with appropriate filters, the basic streak interferometer can be modified to produce 2, simultaneous, streak interferograms at selected wavelengths.

While the refractivity of a free electron gas depends on the incident light directly as the wavelength squared, up to cutoff; the refractivity of a neutral molecule, or an ion with several bound electrons, is relatively insensitive to wavelength. Thus, both mass density and electron concentration in an ionized gas can be measured if simultaneous interferograms at two different wavelengths can be obtained.¹ The sensitivity of the measurement improves as the difference of the wavelengths is made larger.

Figure 1 shows schematically how the basic streak interferometer² has been modified so that simultaneous interferograms at different wavelengths can be obtained. A dichroic mirror-divider with about 85% transmission for the blue line of mercury divides the exit beam of the interferometer. With appropriate filtering, there result two monochromatic beams (λ_1 , $\lambda_2 = 4358$, 5460Å) which are reflected at a small angle to each other through separate portions of the camera lens, thence to fall on the rotating mirror. Displaced streak images can then be obtained on the film drum. Since the position at which the streaks occur can be controlled by a triggering pulse reflected from one of the back faces of the rotating mirror, two film strips of different spectral characteristics can be placed on the drum and chosen so as to have optimum sensitivity at the wavelengths selected.

The present scheme has the limitation that only short duration phenomena, $0 \leq t \leq 20 \mu \text{ sec}$, can be recorded simultaneously without overlap on the film drum. An alternative method, free of this objection, would pass the beams through separate lenses to converge on the rotating mirror at a larger angle.

Figure 2 shows simultaneous interferograms of a cylindrical copper wire exploding into ambient argon at 1/8 atm pressure. Because fringe width is smaller in light of the shorter wavelength, the blue interferogram shows more clearly the boundary³ between the ionized region and the external non-conducting flow whose outer limit is the head shock wave. Because changes in electron concentrations are more sensitively rendered in the light of longer wavelength, the green interferogram shows more clearly the weak shock wave reflected from the tip of the expanding metal vapor.

Complete density and electron concentration charts obtained by reducing simultaneous interferograms obtained by the present method will be discussed in a subsequent paper.

F. D. Bennett

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H. S. Burden

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D. D. Shear

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REFERENCES

1. Alpher, R. A. and White, D. R. Phys. Fluids 2, 162 (1959).
2. Bennett, F. D., Shear, D. D., and Burden, H. S. J. Opt. Soc, Am., 50, 212 (1960).
3. Bennett, F. D. Phys. Fluids, 5, 891 (1962).

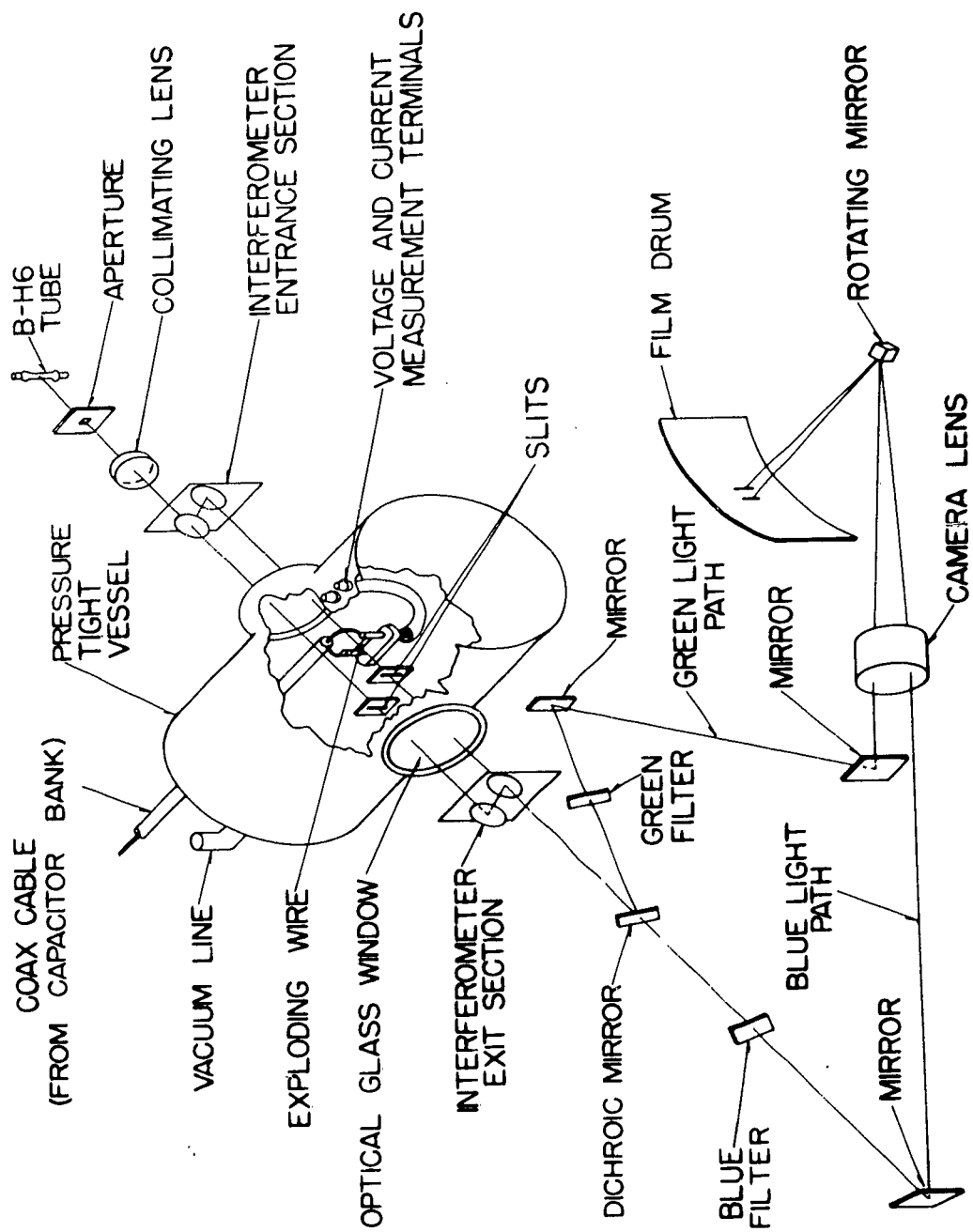


FIGURE 1. Schematic diagram of two-wavelength streak interferometer.

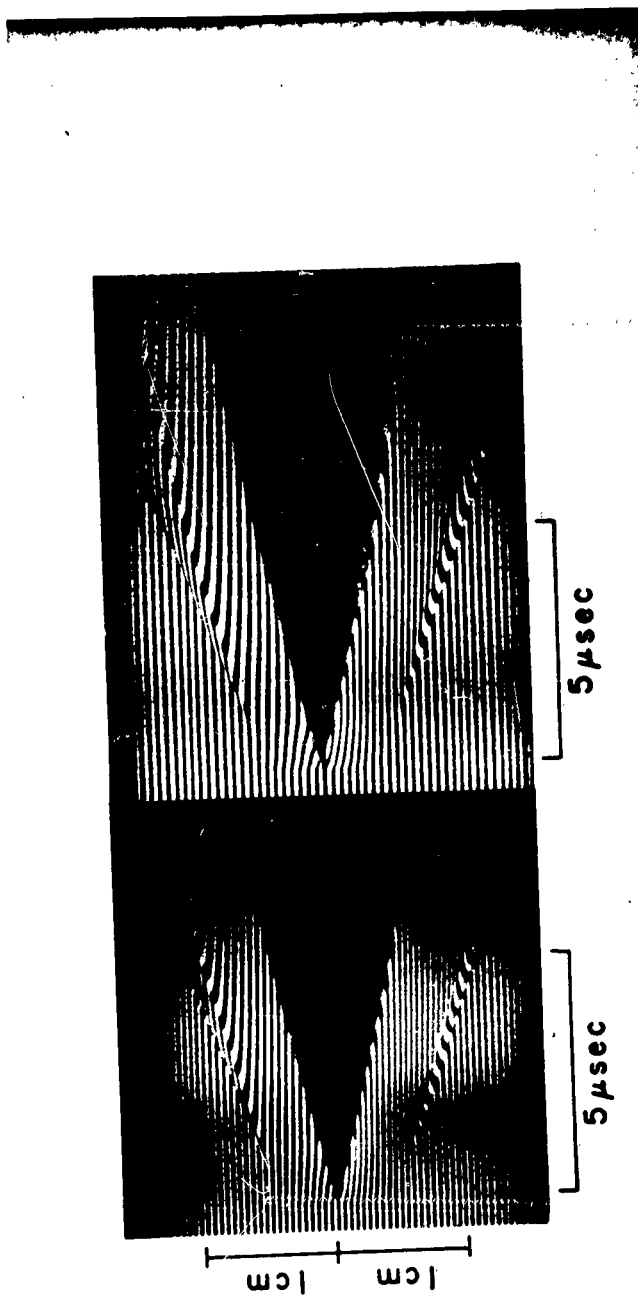


FIGURE 2. Simultaneous interferograms at $\lambda_1 = 4358\text{\AA}$ (left side) and $\lambda_2 = 5460\text{\AA}$ of 4 mil Cu wire at 20 kv into argon at $1/8\text{ atm}$.

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